SAND2011-8816C

PAT-1 Plutonium Air Transportable Package

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November 29-December 1, 2011

AWE PAT-1 Operations Meeting
Aldermaston, UK

* Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation,
for the U.S. Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

NNSA National Nuclear Security Administration

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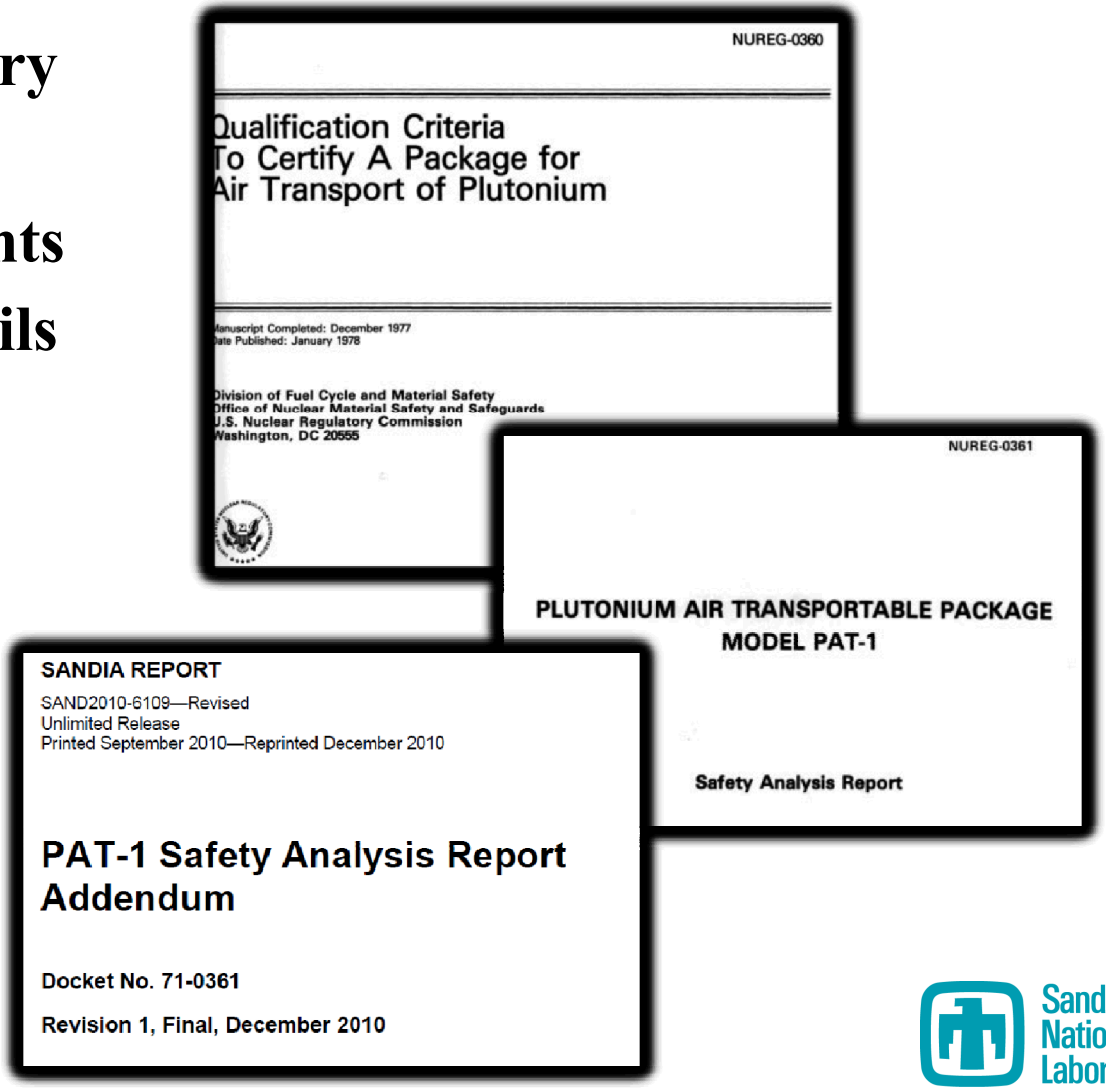
Outline

- Background/History
- Package Design
- Authorized Contents
- Construction Details
- Analysis
- Operations
- Leak Testing



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Background

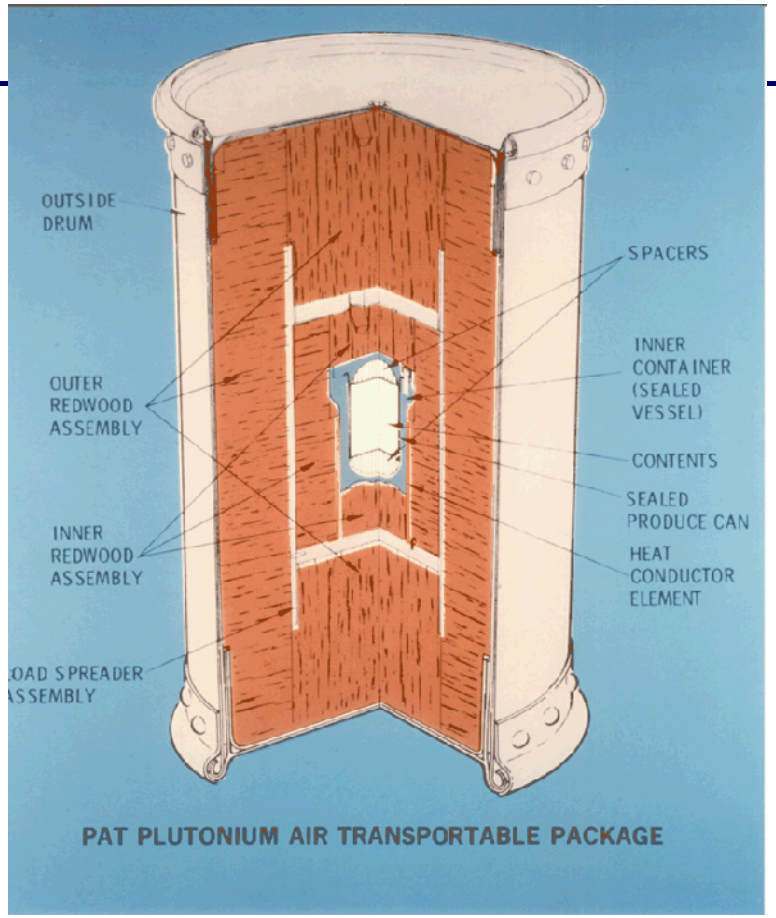
- Public concern with shipment of hazardous materials through populated areas
- In 1975, US Congress banned the shipment of plutonium by air until a container could be developed that could safely survive the crash of a modern aircraft without losing its contents.
- In 1976, USNRC began to prepare qualification criteria to certify a container for air transport of plutonium. These new criteria required the package to pass a new sequence of tests.
- NRC asked Sandia to work with them to develop a shipping package to meet the criteria.
- Sandia worked closely with NRC on package development program, numerous visits and correspondence.
- Results presented to
  - Advisory Committee on Reactor Safeguards
  - National Academy of Engineering

Package Identification and CoC – PuO_2

- **Plutonium Air Transportable Package, Model PAT-1**
  - **Certificate No. 0361 issued to NRC**
  - **Package ID number – USA/0361/B(U)F-96 (meets IAEA 1996 regulations)**
  - **Meets criteria specified in NUREG-0360, *Qualification Criteria to Certify a Package for Air Transport of Plutonium***
  - **Meets criteria specified in 10CFR Part 71**
  - **Original Authorized Contents**
    - **PuO_2 and daughter products**
    - **PuO_2 may be mixed with UO_2 and daughter products**
    - **Maximum 2 kg of PuO_2**
    - **Maximum decay heat of 25 watts**
  - **Qualifies as Fissile Class 1**
  - **First certified in 1978**

PAT-1 Air Transportable Package (USA/0361/B(U)F-96)

- Major Components
  - AQ-1 Protective Overpack (454 lb)
  - TB-1 SS Containment Vessel (37 lb)
  - PC-1 SS Product Can (0.3 lb)
  - Contents (maximum) (4.4 lb)
- Gross Weight: ~500 lb
- Dimensions: 24 ½ in. dia. x 42 ½ in. height



- Double stainless steel drums
- Grain-orientated redwood
- Load spreader

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PAT-1 Package Transport Test Environments

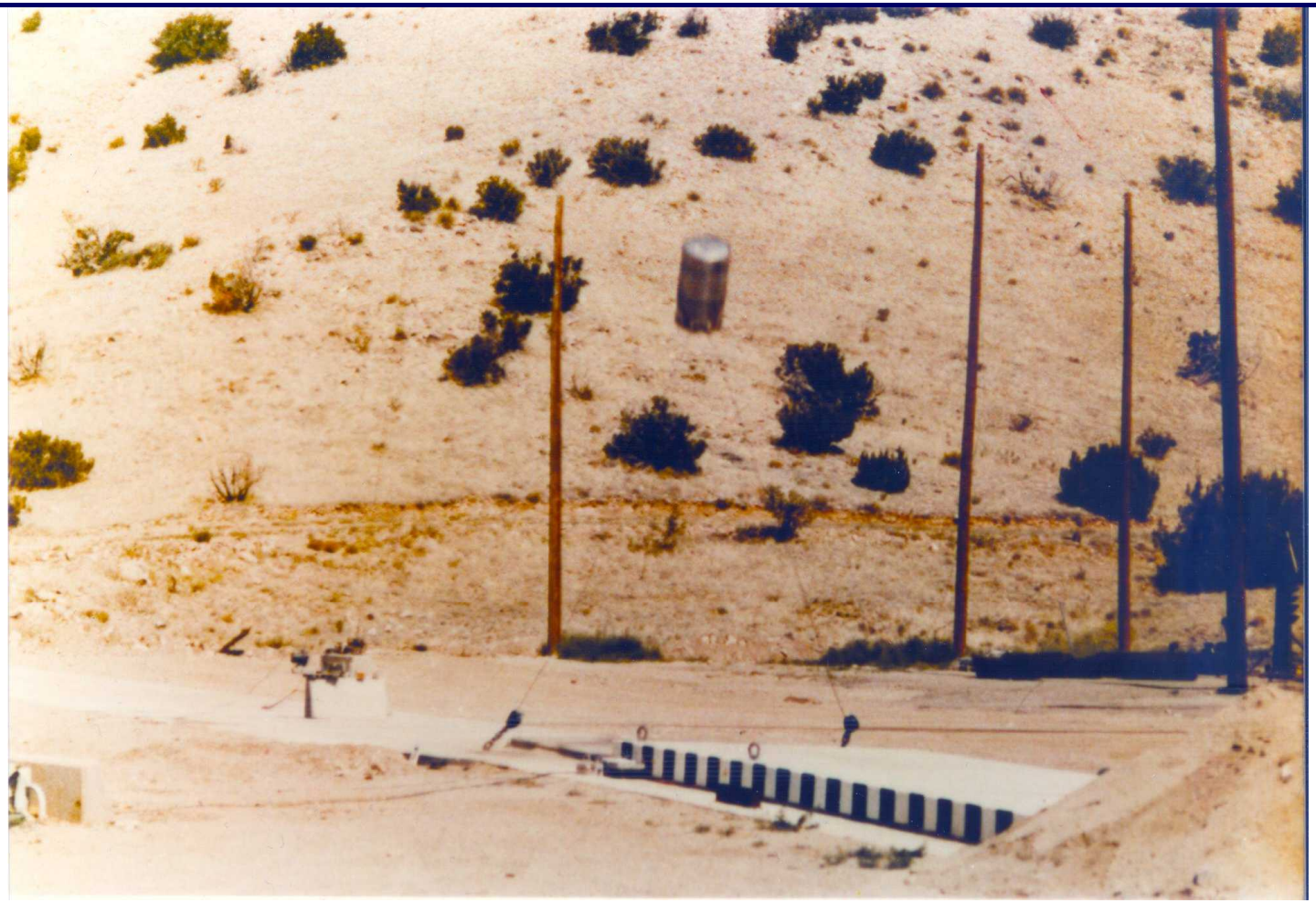
71.71 Normal conditions of transport

71.73 Hypothetical accident conditions

71.74 Accident conditions of air transport of plutonium

- **Right angle 129 m/s (422 ft/sec) impact onto an unyielding surface in most damaging orientation**
- **2-inch wide steel bar static beam compressive load of 31,800 kg (70,000 lbs) to result in maximum damage**
- **227 kg (500 lb) pointed solid probe (right circular cone) dropped from 3 m (10 ft) on most vulnerable point**
- **1.8 m (6 ft) structural steel angle (legs 13 cm (5 inch) long, 1.3 cm (½ inch) thick) from height of at least 46 m (150 ft) onto package two times**
- **One hour JP-4 or JP-5 pool fire test, package cooled naturally or water cooled, most damaging environment**
- **0.9 m (3 ft) immersion test for 8 hours**

PAT-1 High Speed Impact Test



DOE Program Needs: Air Transport of Pu Metals

- **Support critical national security programs**
  - **Collaborative experiments for stockpile assessments**
  - **Experiments for enhancing code capabilities**
  - **Support stockpile certification and life-extension programs**
- **Material exchanges for experiments**
  - **Study chemistry, metallography, and properties of Pu samples**
  - **Enhance codes through knowledge of material responses**
- **Plutonium metal return**

Goal: Develop capability for air shipment of plutonium metal under US and international regulations

TB-1 Temperature/Pressure Profile for Air Transport Fire Environment

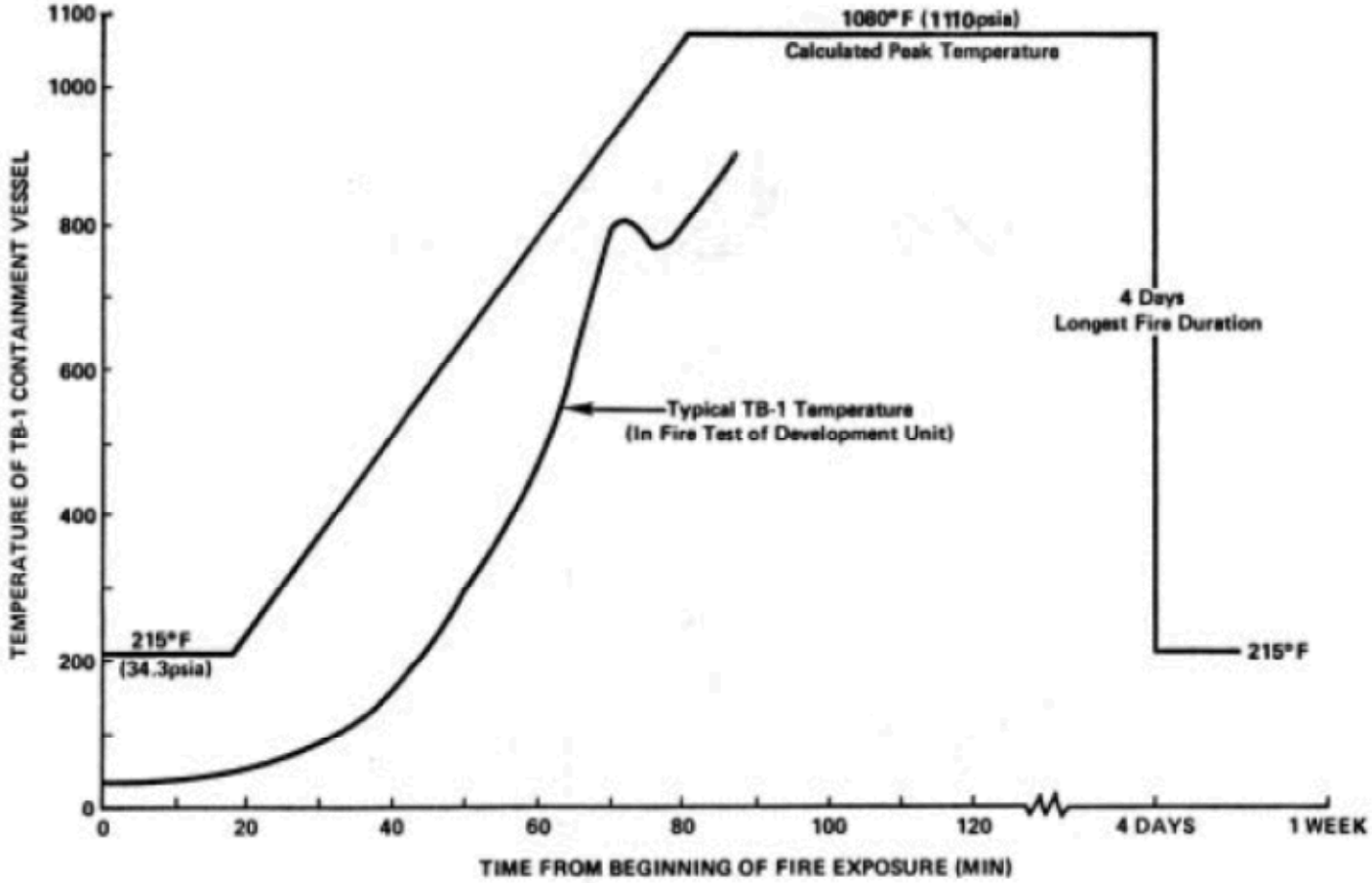


Figure 4.2 Maximum TB-1 Temperature and Pressure Profile During NRC Qualification Criteria Fire Test

(Page 4-6, NUREG-0361 SAR)

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Two Major Technical Issues Addressed

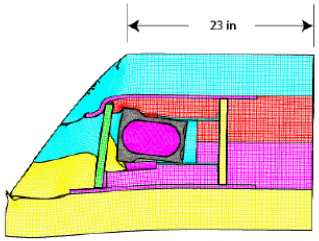
- **PuFe Eutectic**
  - **TB-1 post fire temperature is 582°C (1080°F), four days**
  - **Plutonium melting temperature is 639.4°C (1182.9°F)**
  - **Aluminum melting temperature is 660°C (1221°F)**
  - **PH13-8Mo melting temperature range is 1404 to 1471°C (2560 to 2680°F)**
  - **PuFe eutectic theoretically exists as low as 410°C (770°F)**
- **Contents Response with TB-1**
  - **Internal component impacts must be considered**
  - **PuO_2 density ranges from 1.62 gm/cc and higher (occupies most of the volume within TB-1)**
  - **Pu metal density is about 17 gm/cc (results in compact geometry)**
  - **Maintain 2.1 kg total internal contents weight**

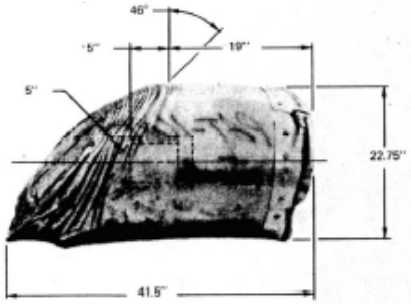
Titanium Inner Packing Developed and Evaluations Supported by Several Organizations

- Concept, authorized contents and eutectic evaluation by LANL
- Pressure evaluation by LANL and SNL
- Leak rate and containment analysis by Y-12
- Leak test procedure developed by Leak Testing Specialists
- Criticality and shielding analysis by ORNL
- Structural and thermal analysis by SNL
- External reviews by PCD, Energy Solutions, and SRNL

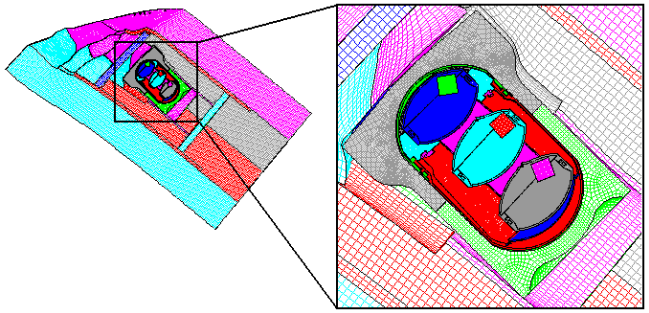
Structural Evaluation of Titanium Inner Packing by Analysis

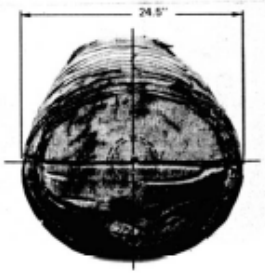
- Performed full body evaluation of PAT-1 overpack and containment vessel, example shows comparison with full scale center of gravity over corner test result





- Analyzed inner packing response, same orientation





- Used component test-generated “strain locus” (in stress triaxiality vs. equivalent plastic strain space) and an empirically-based analytical failure criterion called “Tearing Parameter” to demonstrate integrity

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PAT-1 Certificate of Compliance for Pu Metal

NRC FORM 618
(8-2000)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION

CERTIFICATE OF COMPLIANCE
FOR RADIOACTIVE MATERIAL PACKAGES

1 a. CERTIFICATE NUMBER	b. REVISION NUMBER	c. DOCKET NUMBER	d. PACKAGE IDENTIFICATION NUMBER	PAGE		PAGES
0361	10	71-0361	USA/0361/B(U)F-96	1	OF	6

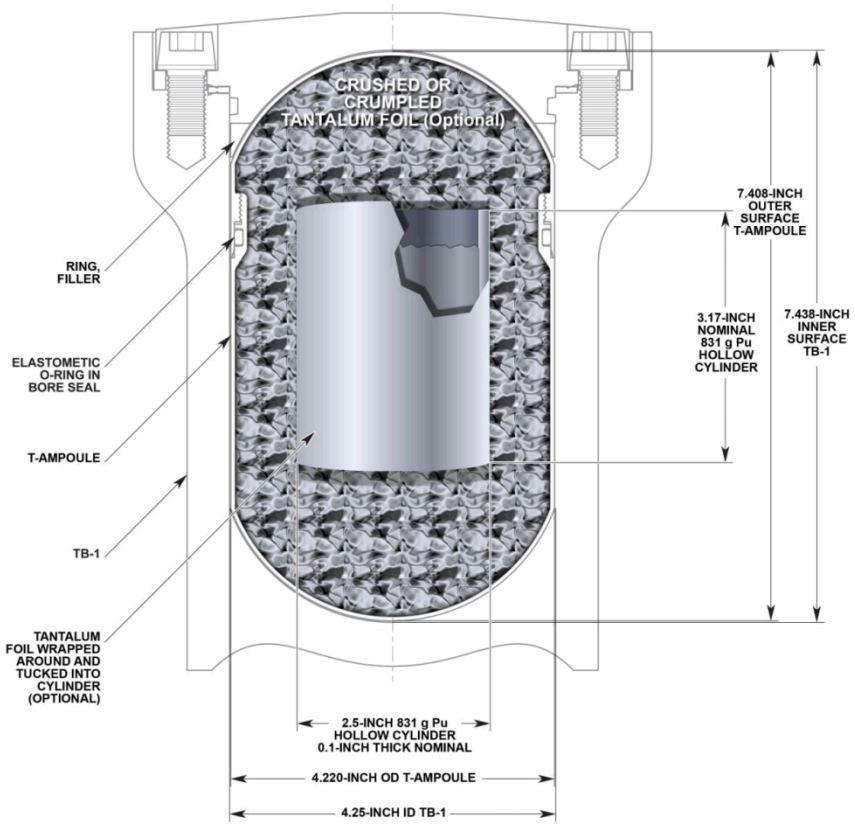
- **NRC issued Revision 10 of the CoC for the PAT-1 package on December 23, 2010**
- **Package Identification Number: USA/0361/B(U)F-96**
- **Issued to: National Nuclear Security Administration**
- **Revised CoC adds plutonium metal sealed within a titanium vessel (designated T-Ampoule) inside of the TB-1 containment vessel as authorized contents**

Pu Metal Authorized Contents

From Table 1-1 in PAT-1 SAR Addendum, authorized contents include

- **Various geometric shapes of Pu metal, including**
  - **Circular discs of varying diameters and thicknesses,**
  - **Rectangular strips of varying lengths, widths, and thicknesses,**
  - **Cylinders in sizes and masses up to those used in the structural analysis,**
  - **Random shapes for chemistry analysis, and**
  - **Composites as specified in Table 1-1**
- **Hollow right-circular cylinders of plutonium metal**

T-Ampoule Provides Eutectic Barrier, Ensures Quality of Product, and is Bulk Container



The titanium T-Ampoule provides

- **Physical barrier between plutonium metal contents and TB-1 containment vessel**
- **Eutectic reaction barrier between the plutonium metal and iron TB-1 alloy at elevated temperatures from fire test**
- **An enclosure to maintain inert cover gas over plutonium metal to minimize oxidation during normal conditions of transport**
- **Container for shipping bulk material (731 – 831 gm Pu hollow cylinder)**

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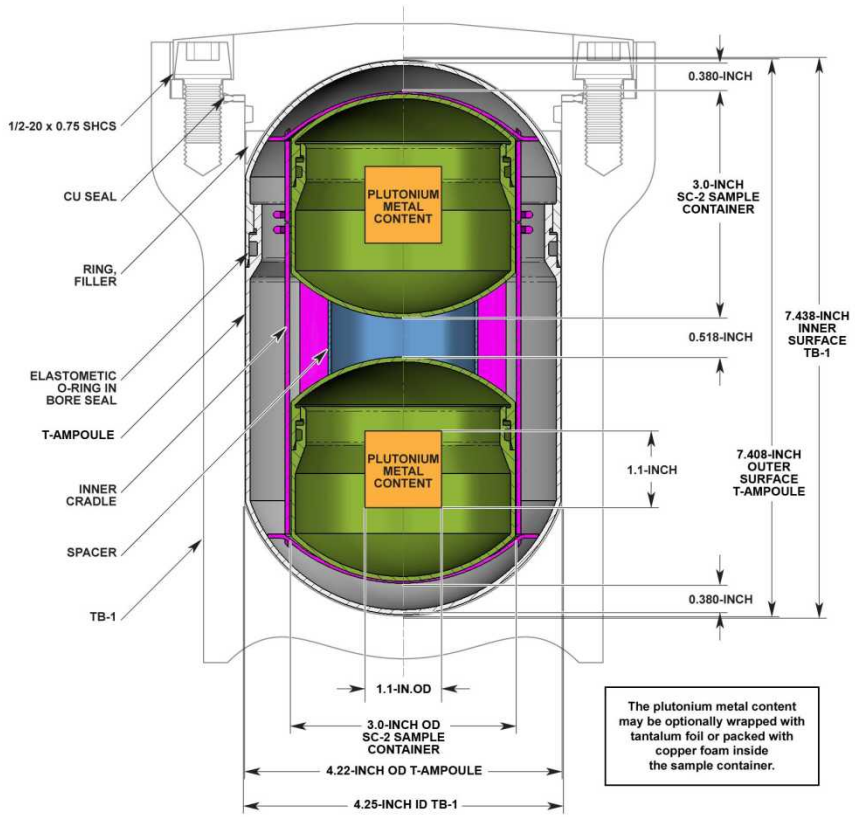
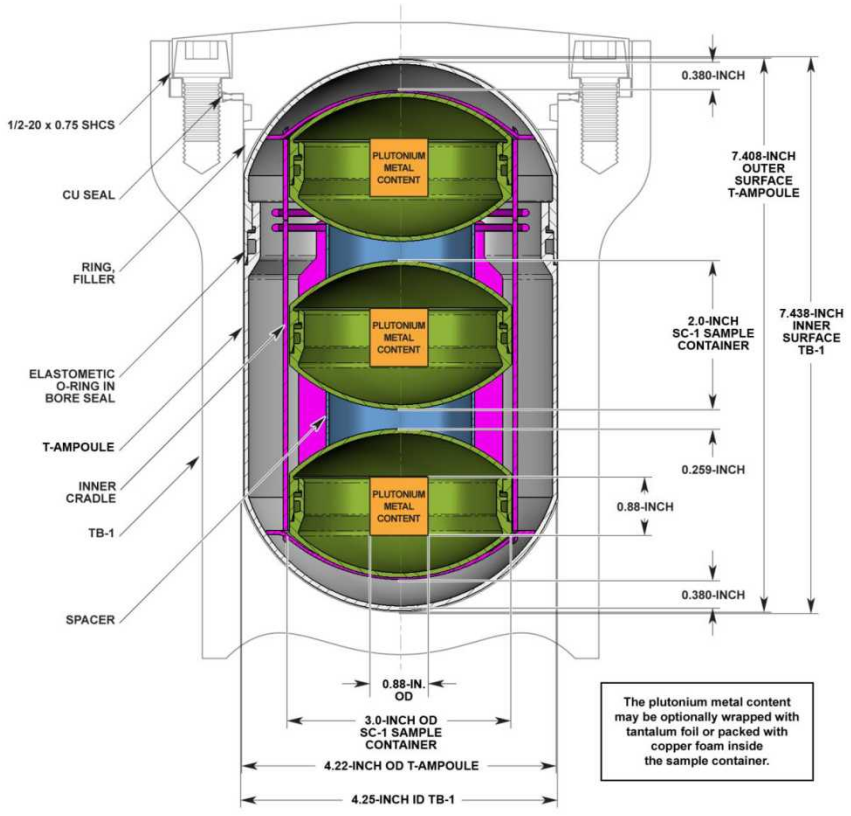
Titanium Sample Containers



Two Sample Container Configuration (SC-2)

338 gm each, 676 gm total

or 60 gm Pu/Be each, 120 gm total



Three Sample Container Configuration (SC-1)

174 gm each, 523 gm total

or 60 gm Pu/Be each, 180 gm total

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Summary of New, Consumable, and Replacement Parts Fabricated

Component	Drawing	Fabricated
Ring Filler	2A0262	3
T-Ampoule	2A0261	6
Inner Cradle	2A0385	3
Sample Container-1	2A0268	18
Sample Container-2	2A0265	12

Consumable/replacement parts include copper gaskets, Viton O-rings, aluminum disc, lifting slings, insulation pads, and shipping skids

Manufacture of Titanium Components

T-Ampoule

- Verify material certifications
- Rough machine titanium stock
- Heat treat
- Final machining
- Tiodize
- Assembly Verification of T-Ampoule with Inner Cradle hardware
- Final QA inspection/acceptance

QA Program for Fabrication of Titanium Hardware and Consumables

- **Corporate SNL AS-PT-PD-04 *Title 10 Code of Federal Regulations Part 71 Packaging and Transportation of Radioactive Material – Quality Assurance Program Plan***
- **Employs Quality Assurance Implementing Procedures (QAIPs) to supplement SNL corporate procedures to meet related elements of Subpart H**
- **Section 9 of the PAT-1 SAR Addendum defines the QA program**
- ***Specifications and Drawings, of the Safety Analysis Report for the Plutonium Air Transportable Package, Model PAT-1* (also in Section 9 of SAR)**

Fabrication of Additional Packages

- Kansas City Plant National Secure Manufacturing Center was contacted by NNSA for fabrication of additional packages
- Fabrication drawings and specifications were reviewed and preliminary cost estimates were developed
- Evaluation being performed to determine fleet size
- Sandia National Laboratories is supporting the preparation of the PAT-1 procurement specification
- The request for quote is in process

PAT-1 Trainer

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Package Description and Loading/Unloading Operations

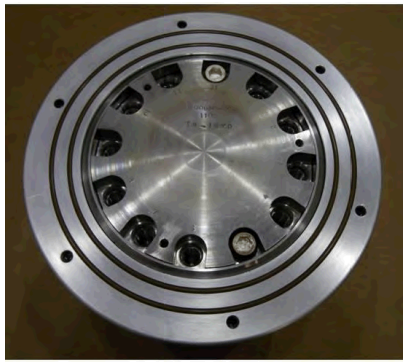
Information from reports (electronic files) entitled

- ***PAT-1 Safety Analysis Report Addendum, Docket No. 71-0361*, SAND2010-6109-Revised, Printed September 2010—Reprinted December 2010, Sandia National Laboratories, Unlimited Release**
- ***Safety Analysis Report for the Plutonium Air Transportable Package, Model PAT-1*, NUREG-0361, U.S. Nuclear Regulatory Commission, February 1978, Unclassified**
- ***PARC (Plutonium Accident Resistant Container) Program Research, Design, and Development*, NUREG/CR-0030, SAND76-0587, July 1978, Unclassified**
- ***PAT-1 Procedure – Copper Gasket Removal from TB-1 Lid***
- ***NRC Certificate of Compliance for Radioactive Material Packages, 0361, Revision 10, USA/0361/B(U)F-96*, December 23, 2010**
- **AAR Mobility Systems, *463L Air Cargo Pallet HCU-10/C***

Leak Testing

Information from reports (electronic files) prepared by Leak Testing Specialists, Inc., sections entitled

- ***TB-1 Containment Vessel Project Report*, August 20, 2010**
- ***TB-1 Containment Vessel Leak Test Requirements*, August 6, 2010**
- ***Helium Mass Spectrometer Leak Test Procedure, Bell Jar Technique, including Addendum I and II*, August 6, 2011**
- ***CALT Pressure Change Leak Test Procedure*, August 11, 2011**
- ***Pressure Chamber Operability Verification*, July 29, 2010**



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Summary

- **PAT-1 metals certification supports critical national security programs, material exchanges for experiments, and metal return**
- **Only package that will meet very severe Pu air transport accident requirements in 10 CFR 71.74**
  - **422 ft/sec impact**
  - **70,000 lb compressive load**
  - **500 lb puncture probe (10 ft)**
  - **Two slash tests (150 ft)**
  - **One hour fire test**
  - **3 ft immersion**
- **Sandia developed Tearing Parameter used to ensure eutectic barrier integrity**

Achieves goal to provide capability for air shipment of plutonium metal under US and international regulations